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Research Note

He2-90: a southern planetary nebula with low metal abundances*

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Abstract. Recent spectroscopic observations are presented for the southern planetary nebulae He2-90. Plasma diagnostics and chemical composition are derived, showing that the object has very low abundances of O, N, S, Ne, and Ar, despite being near the galactic plane. Estimated properties of the central star suggest that this object lies at the low-luminosity region of the HR diagram.

Key words: planetary nebulae: individual (He2-90) – stars: abundances – stars: evolution

1. Introduction

In the past few years, several southern planetary nebulae have been studied by the IAG/USP group, based on observations obtained both in Brazil and in Chile (Freitas Pacheco et al. 1991, 1992 and references therein). Plasma diagnostics and chemical composition have been derived for over 60 nebulae, including a few metal-poor objects which apparently have low mass central stars (Maciel et al. 1990). This group of objects includes SwSt-1, Hu2-1, and, apart from a low heavy elements abundance relative to normal disk planetary nebulae, they seem to contain underluminous central stars, compared to theoretical calculations.

In this note, we report spectroscopic observations of He2-90 (PK 305+01 1), included in our observational programme, which seems to follow the same trend as these objects.

2. Observations and reduction

The spectra were obtained in two observational runs on May 11, 1991 and April 4, 1992; using a Boller and Chivens Cassegrain Spectrograph attached to the 1.6m telescope of the National Astrophysical Observatory (LNA, Brasópolis, Brazil). In the first run a 586×375 pixels GEC/CCD was used as detector while a 1152×770 GEC/CCD was used in the second one. In both cases the resolution was about 7 Å. Besides that, a Coudé spectrum was obtained at our request by A. Damineli on June 6, 1992 in the Hα region, with resolution of about 0.4 Å. Data reduction followed standard procedures, including noise subtraction, flatfield correction, sky subtraction, atmospheric extinction correction, wavelength and flux calibration. This work was done using the VAX 8530 of the IAG/USP and the IRAF package. The observed and the extinction corrected line intensities relative to Hβ are given in Table 1. Typical errors are 30% for the lines weaker than 10 (in the scale I(Hβ)=100) and 15% for the stronger lines. Figure 1 shows the spectrum of He2-90.

3. Physical properties of the nebula

Table 2 gives the derived colour excess, electron temperature and density. The reddening was obtained from the Balmer ratio Hα/Hβ under case B, and compares well with the value derived by Shaw & Kaler (1989). Electron temperature and density were estimated using the auroral to nebular line ratio of [OIII] and [NII].

The ionic abundances were calculated solving the statistical equilibrium equations, including radiative transitions, collisional excitation and de-excitation, for a three-level atom model. Atomic data are from Mendoza (1983). They are shown in Table 3, using the notation ϵ(X)=12+log(X/H).

The elemental abundances have been obtained using the ionization correction factor (icf) as prescribed by Peimbert & Torres-Peimbert (1977) for oxygen and nitrogen. For sulphur, we used the recent icf by Köppen et al. (1991), while for argon the icf was obtained from model calculations by Aller & Czyzak (1983). The resulting values are given in Table 4, using the same notation of Table 3. The helium abundance was derived from the recombination lines HeI$\lambda\lambda$4471, 5876,6678. Collisional effects were taken into account using the formulae

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* Based on observations made at the National Laboratory for Astrophysics - Brasópolis - Brazil

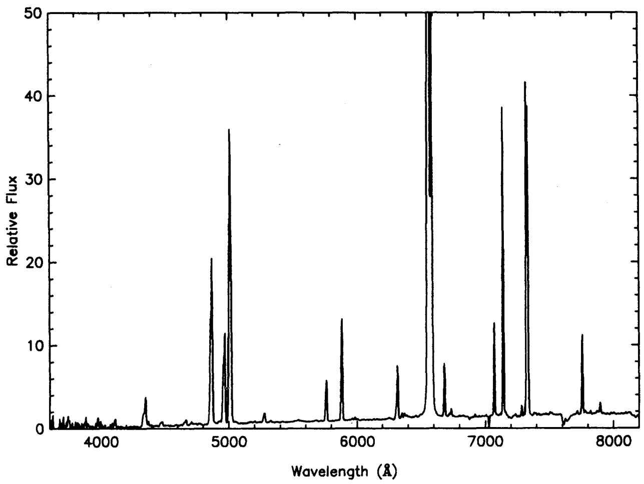

Fig. 1. Optical spectrum of He2-90

Table 1. Relative line fluxes

Ion	I	I_0	I_{model}
[OII]λ3727	7.3:	33.5:	10.4
[NeIII]λ3967	4.8	15.2	11.7
Hδ λ4101	6.9	18.0	29
Hγ λ4340	19.3	36.2	50
[OIII]λ4363	3.2	5.8	3.9
HeI λ4471	3.2	5.1	4.7
Hβ λ4861	100	100	100
[OIII]λ4959 + 5007	235	202	190
[NII]λ5754	17.6	7.4	5.3
HeI λ5875	44.8	17	17.7
[OI]λ6300	4.4	1.2	1.7
[SIII]λ6312	16.8	4.6	4.4
Hα λ6563	1260	287	283
[NII]λ6548 + 6584	260	59.4	45.8
HeIλ6678	16.7	3.5	-
[SII]λ6717 + 6730	3.2:	0.7:	1.9
HeIλ7065	26.6	4.4	10.5
[ArIII]λ7135	85.7	13.6	13.8
[OII]λ7320 + 7330	183	26.1	36.0

Table 2. Physical properties

$logN_e$ (cm^{-3})	T$_e$ (K)	E(B-V)
5.20 $\pm$ 0.15	15000$\pm$800	1.3

by Clegg (1987), but with the R/C ratio corrected by a factor 0.6, following Peimbert & Torres-Peimbert (1987). The derived abundances were checked by modeling the nebula using the code CLOUDY (Ferland 1991). The input parameters were the electron density, elemental abundances and parameters of the central star as effective temperature and luminosity, which will be discussed later. A better agreement between observed and

Table 3. Ionic abundances

Ion	ϵ
S^{+1}	5.25
O^{+1}	7.66
N^{+1}	6.99
S^{+2}	6.28
Ar^{+2}	5.75
O^{+2}	7.38
Ne^{+2}	6.78

Table 4. Elemental abundances

Element	Empirical	Model
He/H	0.086	0.10
ϵ(N)	7.17	7.34
ϵ(O)	7.84	7.84
ϵ(Ne)	7.24	7.22
ϵ(S)	6.51	6.51
ϵ(Ar)	6.32	5.99

calculated line intensities was obtained by changing slightly the empirical abundances. The 'model' values are given in the last column of Table 4 and the predicted line intensities are shown in the last column of Table 1.

The distance to the nebulae can be estimated from the Hβ flux using the Shklovsky method, and correcting by the mass-radius variation (Maciel & Pottasch 1980). The result depends on the angular radius. This was estimated from our Coudé long-slit image, measuring the extent of the Hα emission, which corresponds to an angular radius of about 6". In this case, the derived distance is about d$\simeq$1.5 kpc.

The radial velocity of He2-90 was obtained from our Coudé image and using the forbidden lines [NII]λ6548,6584; [SII]λ6717,6730 and the recombination lines Hα, HeIλ6678. The radial velocity with respect to the Local Standard of Rest is V_{LSR}=-31 km s^{-1}, corresponding to a peculiar radial velocity $|\Delta V_r|$= 8km s^{-1} (see Maciel & Dutra 1992)

4. The central star

The temperature of the central star has been estimated as 51000 K from the Zanstra method for hydrogen (Kaler & Jacoby 1991). A reported uncertain value 15 % higher has been presented for the He temperature by the same authors. The H temperature is comparable to the value found by Preite-Martinez et al. (1991) using the energy-balance method. The luminosity of the central star can be estimated from the distance, colour excess and Hβ flux (cf. Pottasch 1984, 1989). The nebula is compact and dense, being probably thick for radiation in the Lyman continuum, a necessary condition for the determination of the luminosity by that procedure. The derived value is $\log(L/L_\odot) \simeq 3.0$.

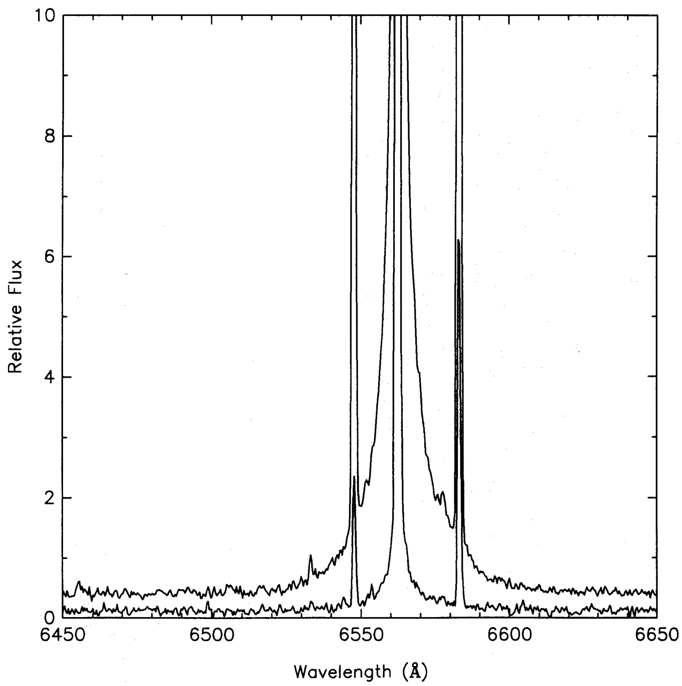

Fig. 2. High dispersion spectrum of the Hα region of He2-90 in two different regions of the nebula. The upper, centered on the star, displays the nebular plus the stellar contribution to the line; the lower, displaced by 6", displays only the nebular contribution

Long slit Coudé spectrum allows a comparison between Hα profiles including only the nebular emission and that extracted from the central region, where the nebula plus the star contributions are present (see Fig. 2).

The Hα profile in the central region presents extended wings due probably to emission in a fast stellar wind, having an expansion velocity of order of 1050 km s^{-1}. From profile decomposition, we estimated the stellar contribution to be about 17 % of the total Hα emission, corresponding to a line emission output of $L_*(H\alpha) \simeq 1.5 \times 10^{34}$erg s^{-1}. The mass loss rate can be computed from the expression (Freitas Pacheco & Veliz 1987)

$$L_* = \frac{\alpha_{H\alpha}(T_e) h\nu_\alpha}{2\pi R V_\infty^2} \left(\frac{\dot{M}}{\mu m_H}\right)^2 2 \ln\left(\frac{V_\infty}{V_0}\right)$$

where $\alpha_{H\alpha}(T_e)$ is the effective Hα recombination coefficient, R=0.38 $R_\odot$ is the radius of the star and $V_0 \simeq 15$ km s^{-1} is the velocity of the sound near the photosphere. The other symbols have their usual meaning. Using the parameters obtained, we derived a mass loss rate of about $\dot{M} \simeq 10^{-7} M_\odot yr^{-1}$.

5. Discussion

The abundances relative to H are generally very low, compared with the average values for galactic planetary nebulae (Maciel 1992). The abundances of O, N, Ne, S, and Ar are compatible with those of type III nebulae, although O, N, and Ne seem underabundant even for that class of objects. Maciel & Dutra (1992) found that the average peculiar radial velocity for type II and type III nebulae are respectively 22 and 64 km s^{-1}. Our derived value for He2-90 is − 8 km s^{-1} for galactic parameters $R_0 = 8.5$ kpc and $\Theta_0 = 220$ km s^{-1} (see Maciel & Dutra 1992 for details), so that He2-90 has kinematical properties characteristic of thin disk objects, which is supported by its low height from the galactic plane ($z = 40$ pc). However, the peculiar radial velocity distribution of type III is quite broad while type II nebulae show a higher concentration toward low values (about 62 % of the objects in this class have $|\Delta V_r| \leq 30$kms^{-1}), so that He2-90 could be placed among the former category, in spite of its low distance to the galactic plane.

Adopting the Zanstra temperature for the central star and the estimated luminosity we can locate this object on the HR diagram. Although the uncertainties are large, especially due to errors in the distance, we notice that the star lies below the lowest evolutionary track generally considered for nuclei of PNe with H-rich spectra (Schönberner 1981; Shaw & Kaler 1985, 1989). Therefore, this object has physical characteristics similar to those studied by Maciel et al. (1990), in the sense that the nebular underabundances are probably explained by the presence of a low-luminosity, low-mass central star.

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